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			<p><b>Published</b> <i>With international search report.</i></p>
<p>(54) Title: A CRANE CONTROL METHOD</p> <p>(57) Abstract</p> <p>The object of the invention is a method of controlling a crane or a similar apparatus, utilized e.g. in controlling an overhead crane, wherein the crane attendant applies velocity request (Vref) from the control system of the crane to the operating means of the crane as control sequences and the velocity requests (Vref) applied by the attendant are read into the control system. To improve controllability of the crane, the velocity request (Vref) is compared to the previous velocity request and if the velocity request has changed, an accelerating sequence for the corresponding change in velocity is provided, subsequently storing the resultant accelerating sequence, whereafter, or if the velocity request remains unchanged, the changes in velocity determined by the stored accelerating sequences at a given time are added up and this sum (dV) is added to the previous velocity request (Vref), the resultant sum providing a new velocity request (Vref2), which is set as a new control command and velocity request (Vref2) for the operating means of the crane.</p>			<pre> graph TD     START([START]) --&gt; READ[READ THE VELOCITY REQUEST Vref APPLIED BY THE ATTENDANT]     READ --&gt; IF{IF THE VELOCITY REQUEST HAS CHANGED}     IF -- YES --&gt; PROVIDE[PROVIDE AN ACCELERATING SEQUENCE FOR THE CORRESPONDING CHANGE IN VELOCITY]     PROVIDE --&gt; STORE[STORE THE SEQUENCE IN THE EXECUTABLE TABLE]     STORE --&gt; ADD[ADD UP THE CHANGES IN VELOCITY DETERMINED BY THE STORED ACCELERATING SEQUENCES AT A GIVEN TIME, AND SET THE SUM AS THE VALUE OF THE VARIABLE dV]     ADD --&gt; Vref2["Vref2 = Vref + dV"]     Vref2 --&gt; SET[SET Vref2 AS A NEW CONTROL COMMAND FOR THE MOTORS OF THE CRANE]     </pre>

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## A crane control method

5 The object of the invention is a method of controlling a crane or a similar apparatus, utilized e.g. in controlling an overhead crane, wherein the attendant of the crane applies velocity requests from the control system of the crane to the operating means of the crane as control sequences, and the velocity requests applied by the attendant are read into the 10 control system.

15 A crane is a generally used apparatus for handling parcelled goods under such conditions where the parcel to be handled cannot be transferred along the floor or ground. Cranes are used, for example, in ports and stores as well as in industry for moving parcels. The principle underlying both the structure of the 20 cranes based on open-loop control, i.e. cranes without feedback, and the methods of controlling them is that a time of oscillation of the mathematical pendulum is calculated on the basis of the known centre of gravity and suspension height of the load suspended from the crane. Control methods based on the mathematical pendulum are relatively simple and useful in practical solutions.

25 In controlling the crane and moving the load undesired oscillation of the load occurs, disturbing the use and operativeness of the crane. It is previously known to use accelerating and decelerating sequences minimizing the oscillation of the load to move the load 30 hanging from the crane. E.g. Finnish Patent 44,036 discloses an apparatus minimizing the oscillation of the load, the apparatus setting a corresponding change in acceleration to follow each change in the acceleration of the control sequence after half the time of oscillation.

The problem with the known solutions is that in them similar fragments of a control sequence added to one another at a certain moment are executed consecutively; and on the other hand, the known solutions 5 require that the previous control sequence should be completed before beginning another control sequence. In the most general control movements of the crane, the execution of the control sequence takes about 4 to 10 seconds, wherefore the known solutions are not very 10 useful in assisting the crane-man. The object of the invention is to provide a control method that eliminates the disadvantages inherent in the prior art and the known solutions. This is achieved by the method of the invention, which is characterized in that the velocity 15 request is compared to the previous velocity request; if the velocity request has changed, an accelerating sequence for the corresponding change in velocity is provided, subsequently storing the resultant accelerating sequence, whereafter, or if the velocity request 20 remains unchanged, the changes in velocity determined by the stored accelerating sequences at a given time are added up and this sum is added to the previous velocity request, the resultant sum providing a new velocity request, which is set as a new control command and velocity request for the operating means of the crane. 25

The method of the invention is based on the idea that the features of the control system of the crane are improved by adding up, in a defined manner, different control sequences eliminating the oscillation 30 of the load after acceleration.

Significant advantages are achieved by the method according to the invention for controlling the crane, the most significant advantage being an improvement in the features of the control system assisting the crane-man. When the method of the invention is used, the 35

desired final velocity aimed at by acceleration can be randomly modified at any moment, also during the actual accelerating and decelerating sequences. Thereby a new desired final velocity is achieved without undesired 5 after-oscillation of the load. In practice also such situations occur where the control system, for one reason or another, sends a false control command, whereby the crane is accelerated toward a new final velocity. Owing to the method of the invention the effect of such 10 false commands on the use of the crane and the oscillation of the load can be effectively eliminated.

In the following the invention is described in greater detail with reference to the attached drawings, wherein

15 Figure 1 shows a schematic view of an overhead crane,

Figure 2 illustrates a velocity sequence functioning as a control sequence,

20 Figure 3 shows a flow chart of the method according to the invention,

Figure 4 shows the executable table of a preferred embodiment of the invention,

25 Figure 5 illustrates the adding up of the accelerating sequences, and the velocity sequence determined by the sum,

Figure 6 illustrates the sum of two divergent accelerating sequences, and the velocity sequence determined by the sum.

According to Figure 1, a trolley 1 of a crane 30 is arranged to be movable along a bridge beam 3 of an overhead crane 2. The bridge beam 3 is further arranged to be movable in relation to end beams 4 and 5 at the ends of the bridge beam 3. From the trolley 1 of the overhead crane 2 is suspended a cable, rope or other 35 suitable suspension means 6 having a hook 7 or other

corresponding means at the end thereof. A load 8 is placed in the hook 7 by means of elevating belts 7a. An elevation height  $l_i$  of the load is regarded as being calculated from the location of the hook 7. Each varying 5 elevation height  $l_i$  of the load 8 ( $i = 1, 2, \dots$ ) corresponds to a time  $T$  of oscillation characteristic of each elevation height  $l_i$ , whereby the time  $T$  of oscillation of the system is as determined by Formula (1)

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$$T = 2\pi (l_i/g)^{1/2} \quad (1)$$

wherein  $g$  = acceleration of gravity.

The crane 2 is controlled by a control system 13 of the crane by means of different control sequences 10, one of the sequences being shown in Figure 2. The control sequence 10 illustrated in Figure 2 is a velocity sequence  $v(t)$  presented as a function of time  $t$ . The control sequence 10 is directed to control operating 20 means 11 of the trolley 1 and operating means 12 of the bridge beam 3 carrying the trolley 1. For example, electromotors can function as the operating means 11 and 12.

Figure 3 shows a flow chart describing a method 25 of the invention for controlling the crane 2 or a similar apparatus, utilized e.g. in controlling different cranes, such as an overhead crane 2, a multi-function crane or a swinging crane, wherein the attendant of the crane 2 transferring the load 8 applies velocity requests  $V_{ref}$  from a control system 13 of the crane to the operating means 11 and 12 of the crane as control sequences 10. The velocity requests  $V_{ref}$  applied by the attendant to the operating means via the control system 13 are read into the control system 13, subsequently 30 comparing the latest velocity request  $V_{ref}$  to the previ- 35

ous velocity request; if the velocity request has changed, an accelerating sequence for the corresponding change in velocity is provided, whereafter the resultant accelerating sequence is stored e.g. in a 5 executable table or the like included in the control system 13. Figure 4 illustrates storage of the accelerating sequences  $a(t)_{5-7}$  and the sum  $\Sigma a(t)$  of the accelerating sequences added up. In Figure 4, the time T of oscillation of the load is 9 seconds long. The sum 10  $\Sigma a(t)$  of the accelerating sequences determines the magnitude of a velocity request  $V_{ref2}$  directed to the operating means 11, 12 of the crane 2.

According to Figure 3, in the following step, or if the velocity request remains the same, the changes 15 in velocity determined by the stored accelerating sequences  $a(t)$  at a given time are added up and this sum  $dv$  is added to the previous velocity request  $V_{ref}$ , the resultant sum providing a new velocity request  $V_{ref2}$ , which is set as a new control command and velocity 20 request  $V_{ref2}$  for the motors or corresponding means functioning as the operating means 11, 12 of the crane. The velocity request  $V_{ref2}$  is set as a control command either for the operating means 11 arranged to move the 25 trolley 1 or for the operating means 12 arranged to move the bridge beam 3 carrying the trolley 1 or for both said operating means depending on what kind of control command the attendant of the crane 2 applies to the control system 13.

In a preferred embodiment of the invention the 30 accelerating sequences  $a(t)$  are stored in a special executable table 14 or the like as illustrated in Figure 4. The accelerating sequences  $a(t)_{5-7}$  corresponding to the detected changes in velocity are stored in the executable table 14. Several accelerating sequences are 35 stored in the executable table 14. The executable table

14 is gone through and the changes in velocity determined by the stored accelerating sequences  $a(t)$  at a given time are added up therefrom, whereby the sum of the changes in velocity at a given time  $t$  is  $dV$ .

5 According to a preferred embodiment of the invention a new velocity request  $V_{ref2}$  is set as a new velocity instruction for the operating means 11, 12 of the crane practically immediately after providing the new velocity request  $V_{ref2}$ , the control system 13 applying a new velocity request  $V_{ref2}$  to the crane 2 before completing the control sequence according to the previous velocity request  $V_{ref}$ .

15 Figure 5 illustrates addition of two accelerating sequences  $a(t)_1$  and  $a(t)_2$ , the sum being  $\Sigma a(t)$ . Figure 5 also shows a velocity sequence  $v(t)$  determined by the accelerating sequences. Figure 5 illustrates a situation where the load is accelerated on two velocity ramps  $v_1$  and  $v_2$ . This can be understood such that at  $t = 0$  the crane attendant applies the velocity 20 that the velocity request  $V_{ref}$  according to the velocity ramp  $v_1$  would result in. Proceeding along the velocity ramp  $v_2$ , the velocity request is doubled by the crane attendant at  $t = 3$  seconds. Both changes in velocity are 25 executed at a similar constant accelerating pulse  $a(t)_{1-2}$ , the time of oscillation of the mathematical pendulum being  $T = 9$  seconds. When the accelerating pulse or the accelerating sequence  $a(t)_1$  is completed at  $t = 9$  seconds, the proceeding again continues on the ramp in 30 the direction of the velocity ramp  $v_1$  and continues parallel thereto until also the accelerating pulse or the accelerating sequence  $a(t)_2$  is completed. Figure 5 also illustrates providing of the velocity request  $V_{ref2}$  from the original velocity request  $V_{ref}$  and the sum  $dV$  of the changes in velocity. The acceleration results in 35 the target velocity  $V_{ref2}$  without oscillation of the

load and without any necessity of first completing the previous control sequence.

Figure 6 illustrates addition of two divergent accelerating sequences  $a(t)_3$  and  $a(t)_4$ , the sum being  $\Sigma a(t)$ . Figure 6 also shows the velocity sequence  $v(t)$  determined by the accelerating sequences  $a(t)$ . This can be understood such that at  $t = 0$  the crane attendant applies the velocity that the velocity request according to the velocity ramp  $v_3$  would result in. At  $t = 4$  seconds, the crane attendant changes the target velocity to  $v(t) = 0$ , i.e. the attendant wants to stop the crane. As above, also here both changes in velocity are executed at a similar constant accelerating pulse  $a(t)_{3-4}$ , the time of oscillation of the mathematical pendulum being  $T = 9$  seconds. The acceleration results in the target velocity 0 without oscillation of the load and without any necessity of first completing the previous control sequence.

Above, the term acceleration should be understood as both positive and negative acceleration, i.e. both as conventional acceleration and as deceleration with the opposite effect.

To carry out the method presented in the flow chart 3, the control unit 13 should comprise a means for applying a control command, a means for reading the control command, a means for comparing the new control command with the previous control command, a means for providing an accelerating sequence, a means, such as an executable table, for storing accelerating sequences, a means for adding up the accelerating sequences and a means for providing a new control command and for applying the control command to the crane. A flow chart of a practical apparatus solution (not shown) would correspond, in outline, to the structure of the flow chart of Figure 3. The solutions in question can be

carried out e.g. by programmable logic.

Although the invention has been described above with reference to the examples illustrated in the drawings, it should be understood that the invention is not limited thereto but that it can be modified in many ways within the limits of the inventive idea presented in the enclosed claims.

## Claims

1. A method of controlling a crane or a similar apparatus, utilized e.g. in controlling an overhead crane (2), wherein the attendant of the crane (2) applies velocity requests (Vref) from the control system (13) of the crane (2) to the operating means (11, 12) of the crane as control sequences (10), and the velocity requests (Vref) applied by the attendant are read into the control system (13), characterized by
  - comparing the velocity request (Vref) to the previous velocity request and if the velocity request has changed, providing an accelerating sequence  $a(t)$  for the corresponding change in velocity, subsequently storing the resultant accelerating sequence  $a(t)$ , and thereafter, or if the velocity request remains unchanged,
    - adding up the changes in velocity determined by the stored accelerating sequences  $a(t)$  at a given time, and adding this sum ( $dV$ ) to the previous velocity request (Vref), the resultant sum providing a new velocity request (Vref2), which is set as a new control command and velocity request (Vref2) for the operating means (11, 12) of the crane.
- 25 2. A method of Claim 1, characterized by storing the accelerating sequences  $a(t)$  in a special executable table (14) or the like, the changes in velocity determined by the accelerating sequences also being added up from said executable table (14).
- 30 3. A method of Claim 1, characterized by setting a new velocity request (Vref2) as a new velocity instruction for the operating means (11, 12) of the crane practically immediately after providing of a new velocity request (Vref2), the control system (13) applying a new velocity request (Vref2) to the

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operating means (11, 12) of the crane (2) before completion of the control sequence of the previous velocity request (Vref).

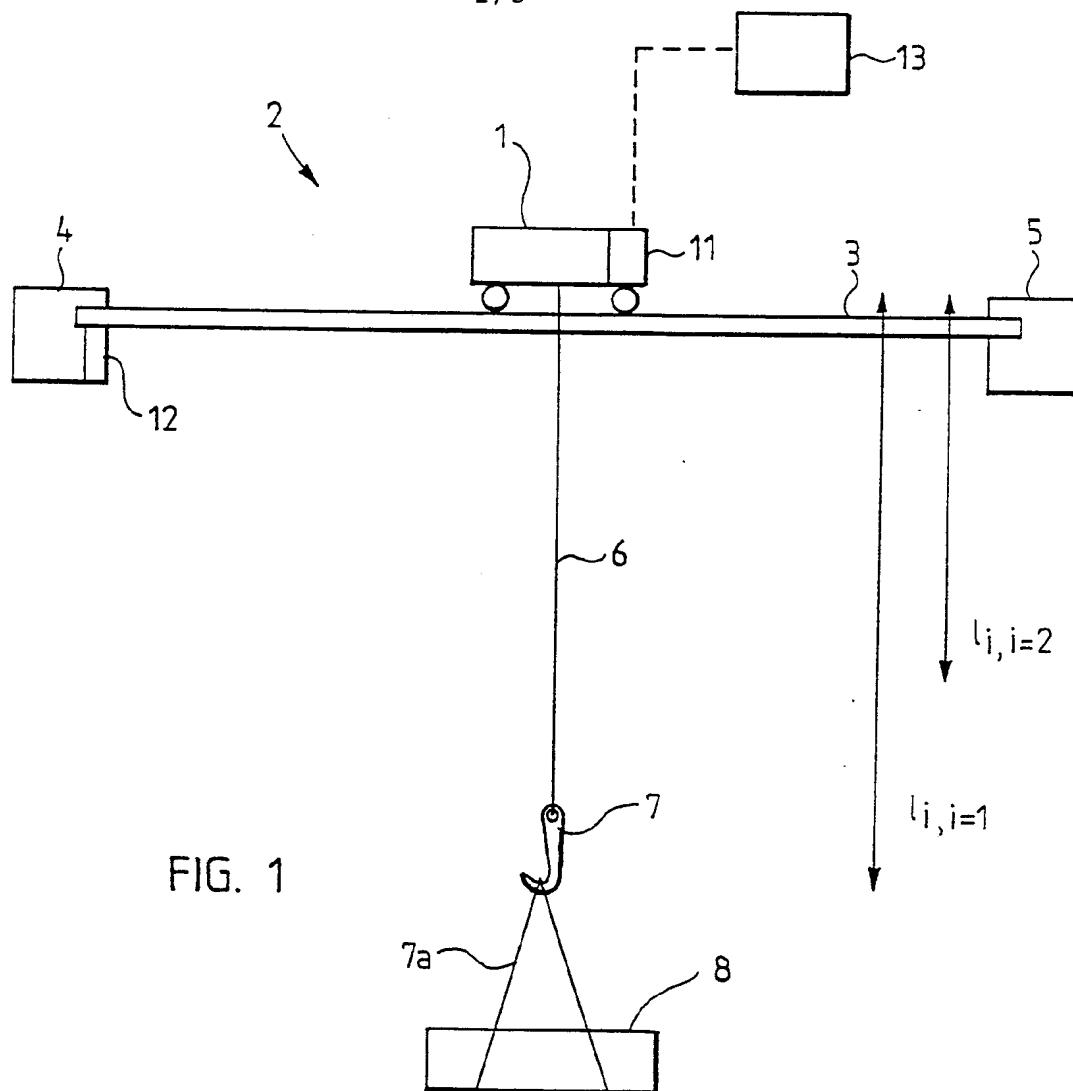


FIG. 1

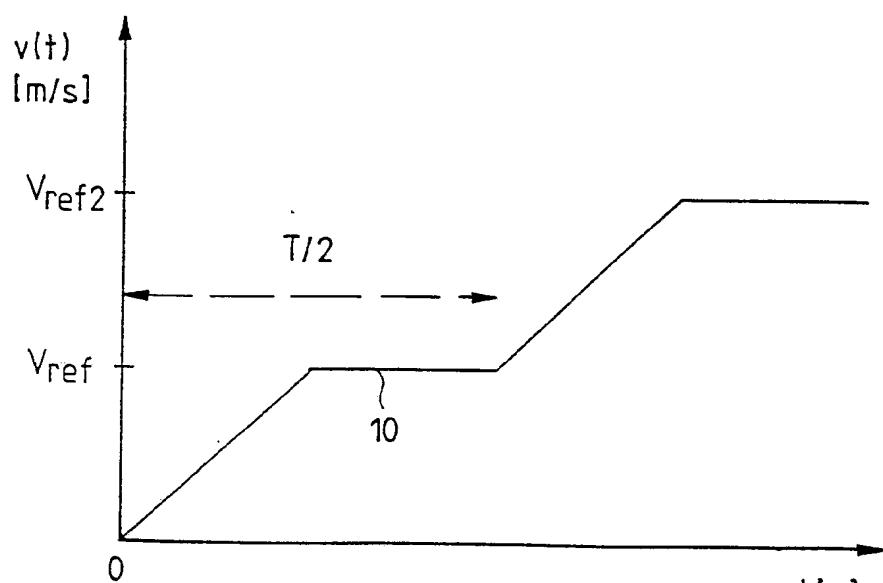


FIG. 2

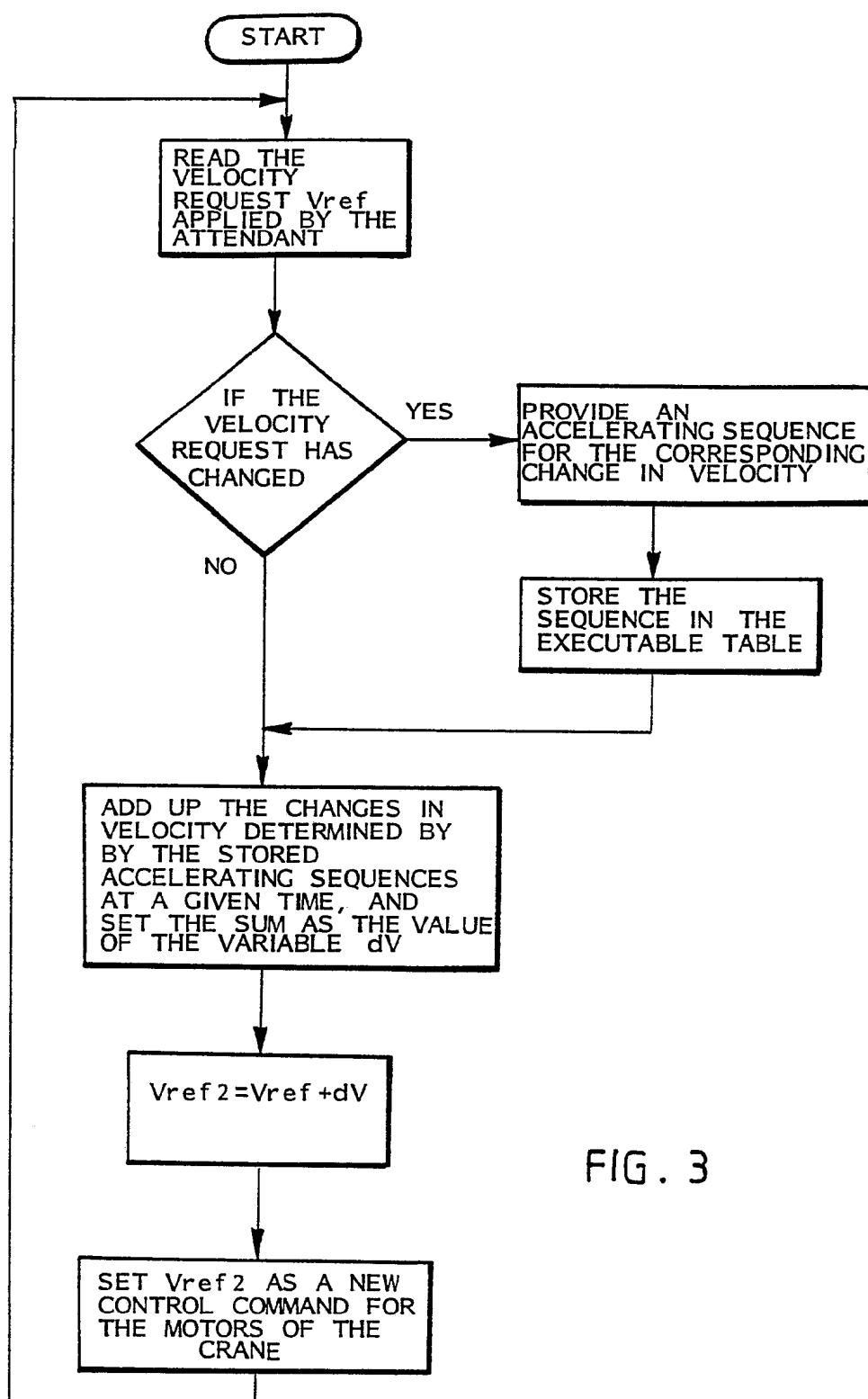
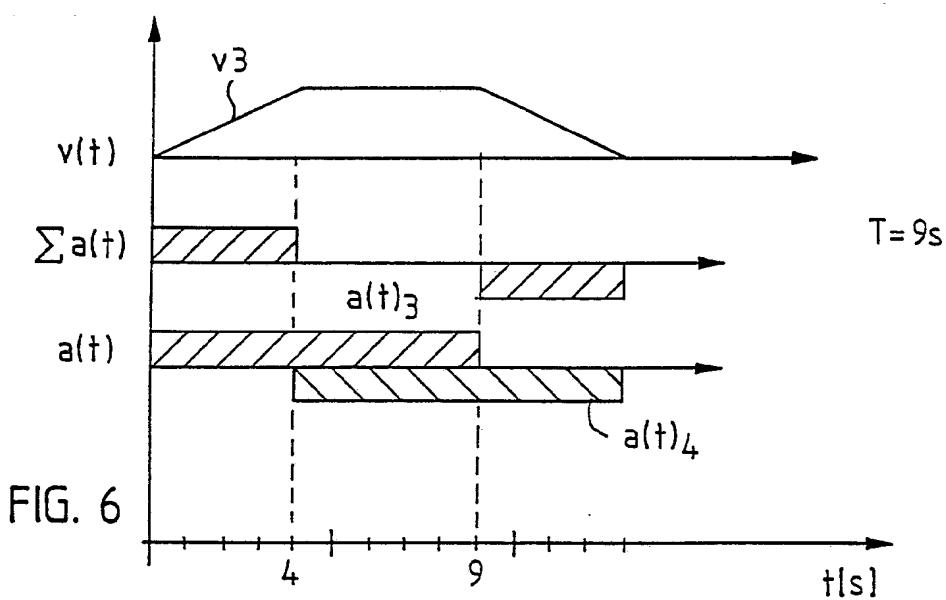
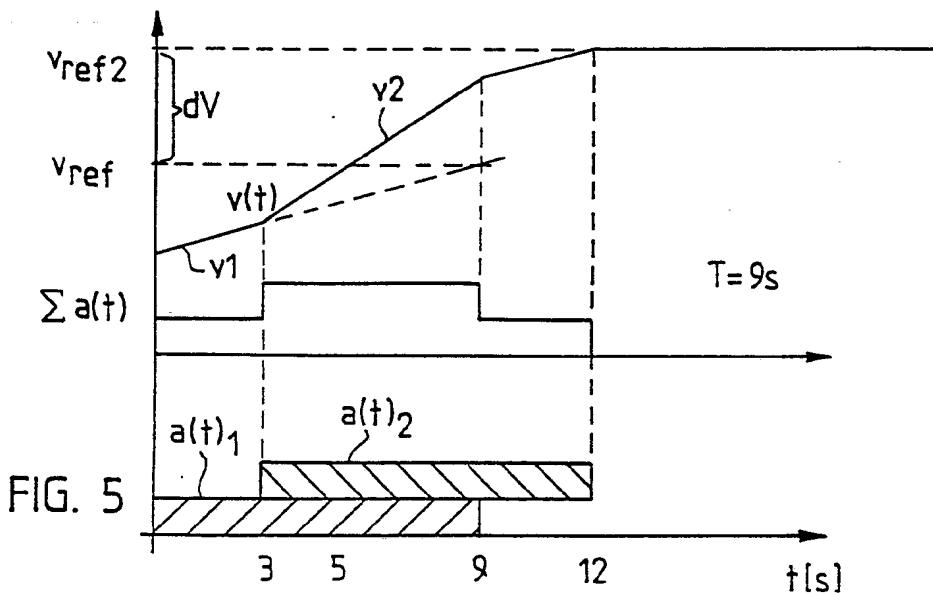
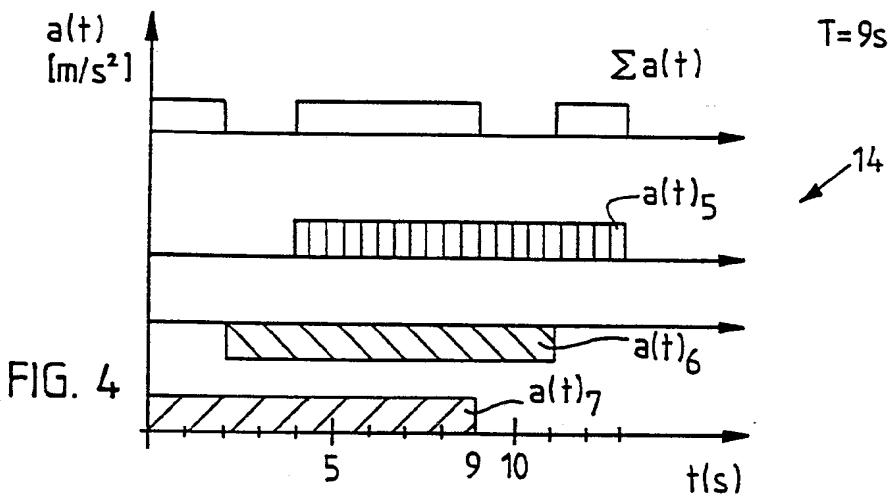


FIG. 3



# INTERNATIONAL SEARCH REPORT

International Application No PCT/FI 92/00111

## I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all)<sup>6</sup>

According to International Patent Classification (IPC) or to both National Classification and IPC

**IPC5: B 66 C 13/06**

## II. FIELDS SEARCHED

Minimum Documentation Searched<sup>7</sup>

Classification System	Classification Symbols
IPC5	B 66 C

Documentation Searched other than Minimum Documentation  
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**SE,DK,FI,NO classes as above**

## III. DOCUMENTS CONSIDERED TO BE RELEVANT<sup>9</sup>

Category <sup>10</sup>	Citation of Document, <sup>11</sup> with indication, where appropriate, of the relevant passages <sup>12</sup>	Relevant to Claim No. <sup>13</sup>
Y	GB, A, 1391245 (SIEMENS AKTIENGESELLSCHAFT) 16 April 1975, see page 1, line 34 - line 56; claim 1	1
A	---	2-3
Y	GB, A, 1132967 (DAVY AND UNITED INSTRUMENT LIMITED) 6 November 1968, see claim 1	1
A	---	2-3
A	DE, C2, 3513007 (HITACHI, LTD.) 15 June 1989, see the whole document	1-3
A	Derwent's abstract, No. 84- 61 775/10, SU 1 017 655, publ. week 8410 (AS USSR MECHANICSP)	1-3
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\* Special categories of cited documents:<sup>10</sup>

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## IV. CERTIFICATION

Date of the Actual Completion of the International Search

16th July 1992

Date of Mailing of this International Search Report

1992 -07- 21

International Searching Authority

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Signature of Authorized Officer

  
Joakim Grip



